OBSERVATIONS
UPON
LIGHTNING

WILSON

1773

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OBSERVATIONS

UPON

LIGHTNING,

AND THE

METHOD of SECURING BUILDINGS
from it's EFFECTS,

IN A

LETTER to Sir CHARLES FREDERICK, &c. &c. &c.

BY

B. WILSON, F.R.S. and Ac. Reg. Up. Soc.
and OTHERS.

LONDON,
Printed for LOCKYER DAVIS, Printer to the Royal Society,
oppoſite GRAY'S-INN-GATE, HOLBORN.
MDCCLXXIII.

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PREFACE.

THE following letter was written in conſequence of a difference in opinion among the members of a committee (of which I had the honour to be one) appointed by the Royal Society, at the inſtance of the Board of Ordnance, to conſider of, and propoſe, the beſt method of ſecuring his *Majeſty's magazines* of gunpowder at *Purfleet* from accidents by lightning.

The ſubject of that difference was this: whether the metal propoſed for Conductors to thoſe buildings, ſhould be *pointed* at the top or *not*.

A Queſtion, in my judgment, of conſiderable importance, as the quantity of powder lodged in thoſe magazines, is in general ſo very great, that ſhould any accident happen, from an improper conſtruction of ſuch Conductors, the moſt fatal conſequences might enſue.

I therefore thought it behoved the committee to be extremely cautious in recommending *any apparatus* that was *expoſed to the leaſt hazard.* And being myſelf, from experiments and obſervations, thoroughly ſatisfied of the impropriety of pointed Conductors, either in *that* or *any other caſe*, I did not ſcruple to object to the method then propoſed; giving at the ſame time *my reaſons to the committee* for ſo doing. But yet, not without offering another method, which I believe is far leſs liable to objections.

The reaſons for propoſing another method, and the advantages to be expected from it, are fully explained in the following letter, which I took the liberty of addreſſing to Sir Charles Frederick, as a member of the Royal Society; who communicated the ſame to Dr. Maty, the Secretary: wherein he expreſſed the wiſh of his majeſty's Board of Ordnance to obtain every light relative to the beſt method of conſtructing Conductors.

PREFACE.

Theſe letters being read at the Society, *part of the committee*, at the next meeting of that learned body, ſignified by a letter, which was afterwards tranſmitted to Sir Charles Frederick, their adherence to their former opinion. But *without* ſummoning the reſt of the committee, for the reconſideration of this matter; *without* entering into any reaſons; or *without* throwing any more light upon the ſubject.

However, apprehending the following paper will not appear in the Philoſophical Tranſactions for *ſome months*, and conceiving the nature of the ſubject to be of too much conſequence, *at this particular time* *, to admit of delay, I am deſirous to take the earlieſt opportunity of laying it before the public, together with ſome *additional notes*, &c. which I think are material: ſubmitting the whole to the judgment of thoſe verſed in this part of philoſophy; who will, I am perſuaded, beſtow on it all the conſideration and attention that ſo important a ſubject deſerves.

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* See the letter from Sir Charles Frederick, which expreſſes a deſire to have the letter read as ſoon as it could be done with convenience; it being on a ſubject very intereſting to his majeſty's Board of Ordnance.

It is with regret I find myſelf obliged to differ from one who has ſo much merit in electric enquiries as Dr. Franklin. But I truſt that no man of candour will be offended with my entertaining and expreſſing my own thoughts; eſpecially in a matter of ſo much conſequence.

I have been favoured with a letter on this ſubject from one of the committee, Edward Delaval, Eſq. which he has given me leave to inſert in this publication.

March 21, 1773.

B. WILSON.

To Dr. MATY, Secretary to the ROYAL-SOCIETY.

SIR, BERKLEY-SQUARE, DEC. 10, 1772.

HAVING received the incloſed letter, I beg the favour of you to lay it before the Royal Society as ſoon as you conveniently can; for as it is on a ſubject very intereſting at preſent to his majeſty's Board of Ordnance, in regard to powder magazines, we heartily wiſh to obtain every light relative to the beſt method of conſtructing Conductors.

I am, SIR,

Your obedient humble ſervant,

CHARLES FREDERICK.

ON

CONDUCTORS.

To Sir CHARLES FREDERICK,

&c. &c. &c.

SIR,

Read at R. Society, 10 Dec. 1772.

YOUR ſtation as Surveyor-General of the Ordnance being ſuch, as makes the ſubject of this paper particularly intereſting to you, I preſume an apology for this addreſs will be wholly unneceſſary.

Upon an application of the Board of Ordnance to the Royal Society in July laſt, a Committee was appointed, to conſider of the propereſt method for ſecuring the *Magazine* at *Purfleet* from miſchief by lightning; which Committee reported to the Council of that learned body what they thought neceſſary to be done upon that occaſion. The Council afterwards tranſmitted to the Board a copy of that report, together with another paper written by myſelf in conſequence thereof.

For, during the conſideration of that buſineſs, ſome doubts having ariſen in my mind, with regard to the propriety of *points*, which were propoſed to terminate the top of each conductor; and thoſe doubts being founded upon experiments and obſervations, I could not conſiſtently ſubſcribe to that report, nor ſuppreſs my opinion on a ſubject of ſuch importance.

Whatever may be the ſentiments of others reſpecting thoſe doubts, yet they being the reſult of my mature conſideration, I thought it my duty to propoſe them to the Committee; and further to expreſs my *diſſent* in writing to that particular part of their report: giving at the ſame time ſome of the principal reaſons for ſuch diſſent, and referring them, for further ſatisfaction on this ſubject, to a letter which is already publiſhed in the Tranſactions of the Royal Society.

As that diſſent is the origin of this paper, a copy of it is here inſerted.

" I diſſent from the report above, in that part
" only which recommends, that each Conductor
" ſhould terminate in a *point*.

" My reaſon for diſſenting is, that ſuch Con-
" ductors are, in my opinion, leſs ſafe than thoſe
" which are not *pointed*.

" Every point, as ſuch, I conſider as *ſolliciting* " the lightning; and, by that means, not only " contributing to *increaſe* the quantity of every " actual diſcharge, but alſo frequently occaſioning a " diſcharge where it might not otherwiſe have hap- " pened.

" If therefore we invite the lightning, whilſt we " are ignorant of what the quantity, or the effects " of it, may be, we may be *promoting* the very " miſchief we mean to prevent.

" Whereas, if inſtead of pointed, we make uſe " of blunted Conductors, thoſe will as effectually " anſwer the purpoſe of conveying away the light- " ning *ſafely*, without that tendency to *increaſe* or " *invite* it.

" My further reaſons for diſapproving of *points*, " in all caſes where Conductors are judged neceſ- " ſary, are contained in a letter alluded to above, " which is addreſſed to the *Marquis* of *Rocking-* " *ham*, and is publiſhed in the Ph. Tr. vol. 54. " p. 247.

" There are other reaſons alſo which I have to " offer, for rejecting points on this particular oc- " caſion, and which *were mentioned at the Committee.* " Thoſe I ſhall lay before the Royal Society at " another opportunity, for the benefit of the pub- " lic."

B. Wilſon.

Royal Society Houſe,
21 Auguſt, 1772.

Agreeable to the declaration at the end of the above diſſent, I ſhall now proceed to offer my further reaſons for objecting to pointed Conductors.

Experience, which is our beſt guide in all phyſical inquiries, but particularly in electrical ones, every day convinces me, that we know but little of that ſubtile fluid which operates ſo *ſecretly*, and at the ſame time ſo powerfully, upon the earth and its atmoſphere. I confeſs that I am even now leſs acquainted with the principle of its action than I thought I was twenty years ago. The *ſmalleſt differences*, in the circumſtances of our experiments, frequently cauſing very *material differences* in their reſults. And perhaps no one, who has not applied his mind cloſely to inquiries of this kind, could conceive how the *pointing a piece of metal or not* ſhould make any material difference in the experiment.

The electrician has it always in his power to convince any one of the fact, who through inexperience, may be inclined to entertain the leaſt ſcruple about it. For *even from thoſe experiments*, to which it was thought proper to appeal at the Committee, it appeared, that the difference in the effects upon this fluid, between *pointed* and *blunted* metal, is as 12. to 1. *

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* The experiments were contained in a paper, which Dr. Franklin produced and read at the Committee. There was no doubt declared by any one of the Committee, at the Time, of the difference in the effects between pointed and blunted metal being as 12 to 1. I had myſelf indeed experienced even a greater difference. And one principal cauſe for it, I apprehend, might be a difference

A Thunder cloud therefore, according to the above experiment and inference, the circumſtances of it being ſuppoſed to be nearly ſimilar with what is called the Prime Conductor in thoſe experiments, if it acted at 1200 yards diſtance upon a point, would require a blunted end to be brought within the diſtance of 100 yards; and beyond thoſe limits would paſs over it without affecting it at all. On this occaſion permit me to obſerve, that the *longer* the Conductors are above any building, the *more danger* is to be apprehended from them; as they will in that caſe approximate nearer in their effects to thoſe that are pointed. And that is one reaſon, why I was not for adviſing the propoſed Conductors at *Purfleet* to be ſo high as *ten feet* above the magazines; and more particularly upon that building called the *Board-houſe*, which ſtands conſiderably higher than the magazines themſelves.

But before we advance farther into this ſubject, it may be proper to ſhew the reaſons for introducing a *pointed* apparatus, when the experiment upon lightning was *firſt* propoſed: what good conſequences were derived from that experiment: and why, upon further

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difference in the ſharpneſs of the point I employed. For it ought to be underſtood in thoſe nice experiments, and which I do not find has hitherto been noticed by any one in theſe reſearches, that a mechanical point is an *indeterminate expreſſion*; as ſuch points may differ greatly in the degree of ſharpneſs, according to the nature of the material, and the ability of the workman who forms them. And a very ſmall difference in thoſe reſpects will, it is well known, make a conſiderable difference in the effects upon this fluid, when they are oppoſed properly to any body that is electrified.

further experiments and obſervations, ſuch points ought now to be laid aſide: when our intention is *not to make electrical experiments*, but by the means of Conductors, to *preſerve buildings from the dangerous effects of lightning.*

Dr. Franklin, in his conjectures, that lightning and electricity were one and the ſame fluid, conſidered how he ſhould *invite*, or *bring down and collect the lightning*, ſo as to make experiments upon it.

And he concluded from obſervation, that the likelieſt method would be, to make uſe of ſuch an apparatus for the purpoſe, as was moſt ſuſceptible of electric effects; or, in other words, ſuch an apparatus as would receive the electric fluid with the greateſt eaſe.

Repeated experiments taught him, that *metals* had the property of receiving that fluid with more eaſe than other ſubſtances.

He alſo learnt, from the like experience, that metals, *by being pointed*, were rendered ſtill more ſuſceptible of receiving it.

And therefore he propoſed an experiment to be try'd, whether it was not in our power to invite, or bring down the lightning, by an apparatus conſiſting of "an *electric ſtand*, and an iron rod 20 or 30 feet "in length, riſing upright from the middle of the "ſtand, and at the top terminating in a very *ſharp* "*point*." This apparatus was recommended to be put upon ſome high building, with the expectation, that if a thunder cloud ſhould happen to paſs near this apparatus, ſome quantity of lightning, depoſited therein, would probably be collected in the rod, by means of the very *ſharp point*, and the *electrical ſtand* at the foot of the rod.

That this contrivance anſwered the end he firſt propoſed, we have had ſufficient evidence.

And it is no wonder, if after this great diſcovery, we find him, and other electricians, purſuing new experiments of this kind, and raiſing thoſe points higher into the air, to collect ſtill greater quantities of that fluid which occaſions lightning. Nor need we be ſurprized, after knowing that lightning could be brought down from the heavens by ſo ſimple an apparatus, and after experiencing its ſubtile effects to be ſimilar to the electric fluid, that the Americans and others, upon Dr. Franklin's recommendation, adopted the principle of ſecuring their buildings from its miſchievous effects, by raiſing, above their houſes, rods of iron *very ſharply pointed*, and applying *wires* from the lower ends of thoſe rods, down the outſide of their houſes to the ground.

But though there appeared many arguments at that time in favour of ſuch Conductors, yet experiments and obſervations at laſt, induced Dr. Franklin to *alter his opinion* in reſpect to thoſe *wires*; and to ſubſtitute, in their place, *rods of iron*; ſtill retaining the principle of having the rods at the top *ſharply pointed*. And many of the Americans, as well as Europeans, approved of the alteration, as appeared afterwards, from conſtructing their Conductors accordingly.

About that time great attention was given, and many new experiments were made, in conſequence of the frequent dangerous effects which lightning was obſerved to produce in ſome valuable buildings, by rending and daſhing to pieces very large ſtones, and timbers, which were connected together by cramps and bars of iron; and at other times, breaking and melting part of thoſe rods, and ſometimes *exploding wires*, even of a conſiderable thickneſs, like ſo much gunpowder.

From careful obſervations of theſe extraordinary appearances produced by violent ſhocks of lightning; and upon making other experiments relating to a certain reſiſting power *in*, or *upon*, all bodies, which appears to act againſt the attacks of lightning, as well as againſt the electric fluid; philoſophers were enabled to aſſign the reaſon, and it is apprehended upon a ſolid foundation, why Conductors ſhould be made of *metal*, in preference to all other materials: as the power of reſiſting ſuch attacks is leſs in metals, than in wood, brick, ſtone, or marble.

And that this reſiſtance might be the more ſimple and uniform, it appeared moſt eligible to have the Conductors made of *one continued piece of metal only*, and of *an equal diameter throughout*. But what that diameter ought to be, depended upon other circumſtances, ſome of which are taken notice of in a former paper referred to above, which I laid before the Royal Society.

By this hiſtorical ſketch, we ſee the propriety of Dr. Franklin's introducing points, and the advantage philoſophy has derived from them: by aſcertaining that lightning, and electricity, are one and the ſame fluid: which appears to be diffuſed every where, at leaſt upon *this earth* and in the *atmoſphere.*

But ſince this important fact has been diſcovered, and repeated experiments had taught us, that we have it in our power to collect that fluid which occaſions lightning; this manner of invitation, viz. by uſing points, *ought,* in my opinion, *to ceaſe* *. Becauſe a greater quantity of lightning than we have yet experienced, may chance to attack us.

For we are ſo far from knowing how great the magazine of lightning may be in the atmoſphere, or in the earth, when it is ready to diſcharge itſelf, either by one, or more exploſions, that we are *ignorant even of the quantity actually diſcharged,* whenever any ſtroke from lightning viſits us.

Nor can the ableſt philoſopher *fix the limits of the greateſt diſcharge* that may poſſibly happen.

Seeing then how vain it is to look for any thing like *abſolute Security* in all caſes; it ſurely behoves us *to proceed with caution:* and it is for that reaſon I have always conſidered pointed Conductors as being unſafe, by their great readineſs to collect the lightning in too powerful a manner. And leſt the Conductors, without ſuch points, ſhould be too ſlender for very violent attacks, in places of great conſequence, I have always recommended the having them above four times larger in diameter, than what are commonly made uſe of.† To the end that our ſecurity may be the greater, by opening a larger paſſage

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* Unleſs where the electrician, like *profeſſor Richmann,* (who was killed by it,) at his *own hazard,* chuſes to make further obſervations on lightning.

† This was the caſe with St. Paul's Church, when Conductors were recommended for that building.

paſſage for any extraordinary diſcharge; and ſo far leſſening the danger to be apprehended from it.

I ought not, in this place, to omit taking notice of a paper, containing ſome further experiments and obſervations, which was produced at the Committee, to ſhew, among other things, that pointed metals were more diſpoſed to receive the lightning, by virtue of a repelling principle in lightning, as well as in the electric fluid, which acted upon the *natural quantity* of the fluid contained *within part of the metal*, to a conſiderable diſtance from the *point*, cauſing, if I may be allowed the expreſſion, a kind of *vacuum* therein.

So far from diſputing this philoſophy, I readily admit the fact.

But I am afraid, *every attempt* to prove that pointed Conductors may be ſo diſpoſed to receive this fluid more readily, at the point, will not mend the argument in the leaſt; becauſe the more we leſſen the power of reſiſting, (even ſuppoſing the whole Conductor in that ſtate) the more we increaſe the power of invitation.

In regard to other experiments, with "*locks of cotton* *, which are acted upon in a particular manner by the appoſition of points; and the concluſions drawn from thence, in favour of *pointed Conductors*, as cauſing ſimilar effects upon the *fragments, or ſmall clouds*, which hanging below the *thunder clouds*, have been ſuppoſed a kind of *ſtepping ſtones* for the lightning to paſs upon towards the earth;

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* See Dr. Franklin's Experiments.

ſuch *pointed Conductors* being *ſuppoſed* to occaſion thoſe fragments to *retire up into the cloud* from whence they were ſuſpended; and on that account, to prevent a ſtroke from lightning, which might otherwiſe have happened. I ſhall for the preſent wave entering into this philoſophy, as I could wiſh the conjecture to be *reconſidered*; becauſe I apprehend it is liable to many objections, which to enumerate would carry me beyond the proper bounds of ſuch a paper as this. However, if the ſame opinion ſhould be again offered, and brought in argument, it may be worth while to enter more *deeply* into the enquiry.

If thoſe gentlemen, who argued at the Committee for the *neceſſity of points*, could have made it appear, that ſuch points draw off, and conduct away, the lightning *imperceptibly* and *by degrees, without cauſing any exploſion,* during a thunder ſtorm, (which ſeems to have been once the opinion of Dr. Franklin) I ſhould readily have ſubſcribed to their report.

But experience ſhews us, that the fact is otherwiſe, there being many inſtances, where violent exploſions of lightning have happened to Conductors that were *ſharply pointed.* And *three* in particular, the accounts of which are inſerted in a publication of Dr. Franklin's *, where the *points* were *diſſipated,* or *deſtroyed,* and a ſmall part of an iron rod melted next the points of one of them; and alſo at the ſeveral crooked ends of the rods below, where they were hooked on to each other, and formed the *Conductor* belonging to Mr. Maine in North America. But as thoſe letters are long, and contain ſeveral other

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* Dr. Franklin's Experiments, page 394, 416, 417, &c. Extracts from which are in the Appendix of this publication.

other curious facts, I ſhall reſerve them, together with ſome further obſervations upon the *nature* and *power* of that *reſiſting principle*, which is found to act ſo ſenſibly againſt the attacks of the electric fluid, or lightning, to ſome future diſſertation.

There is no building, that I know of, more expoſed to this kind of danger, than the *Eddyſtone Lighthouſe*, as it ſtands upon a rock in the ſea, ſeveral miles from land. The fixing of a Conductor to that building was thought highly proper; and the fixing of a point upon it, as highly improper. It was therefore reſolved upon to put up a Conductor without a point, that no more lightning might be unneceſſarily ſolicited to the building; and that all the lightning, which accidentally fell on it, might be conveyed away without injuring it. This Conductor was fixed twelve years ago, and the building has ſince received no injury from lightning *.

There is another edifice of great conſequence, I mean *St. Paul's church*, which ſtands much expoſed, from its height, to accidents by lightning. The Dean and Chapter, of that cathedral, thought it an object deſerving the ſerious attention of the Royal Society. A Committee was therefore appointed, in conſequence of their application; and proper Conductors were put up in the ſeveral places where they were thought neceſſary, from the top of the *Lanthorn* to the *Sewers* under ground. And notwithſtanding particular care was taken to have the additional metal, either of a conſiderable diameter, or an equal quantity of it formed into other ſhapes, for the conveniency of the ſeveral places, yet part of thoſe Conductors, conſiſting of iron, in the *Stone Gallery*, ſhewed marks of their having been made *conſiderably hot*, if not abſolutely *red*, by a ſtroke of lightning, which happened in March laſt, as appears by a letter, which I communicated to the Royal Society, from one of the Vergers of that church, Mr. Richard Gould, who had examined the Conductors the morning following, along with Mr. Burton of the ſame cathedral *, and that the appearances

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* *N. B.* A former building, erected for the ſame purpoſe upon this rock, was ſet on fire by lightning.

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* Mr. Gould acquaints us in his letter, that he examined the four Conductors in the lanthorn and ſtone gallery of St. Paul's church the morning after the lightning happened. That no marks whatſoever appeared upon the Conductor to the *South*, which was the firſt he attended to. That he examined next the Conductor to the *Weſt*, and obſerved, " A thick ruſt lying upon the pavement in the ſtone gallery, as if it had been cleaned off, from the Conductor, with a tool: that ſeveral parts of the iron appeared black—particularly the ſcrews or nuts: ſomething like the effects left by gunpowder upon iron or ſteel; or a ſmoaky fire.

That the Conductor to the *North* ſhewed no marks, no more than to the *South*.

But that upon examining the Conductor to the *Eaſt*, he found *ſtronger marks abundantly*, than on the Weſt Conductor——it being much blacker, particularly on the nuts and ſcrews; the ruſt lying in greater quantities on the pavement. And the *extreme part of the Conductor that goes into the water trunk*, ſeemed like a piece of iron, *newly taken out of a forge* by a ſmith, without working it on the anvil.

N. B. Mr. Gould has ſince added to the account in his letter, ſome circumſtances which I apprehend ought not to be omitted. He ſays, that where the end of the Conductor on the Eaſt ſide points towards the water trunk, a ſtone ſurrounds part of it, leaving an interval half an inch wide between them, and about four or five inches long; which is a little more than the breadth of the Conductor. That this interval was *filled* up with *dirt*, and had been ances were in general as the Verger's letter related them to me.—Mr. Delaval and I went there about *a week afterwards* to obſerve them, and their particular ſituations, with the circumſtances attending them; when we were very well ſatisfied with his account, notwithſtanding it had rained in the *interim* for three Days together.

It is worthy of note, that thoſe *Conductors* did not *terminate* in a *point*; nor *was any point* put upon the *croſs* at the top ——————— and yet Dr. *Franklin was of that Committee.*

If points are ſo eſſential to our ſafety, why was not the reaſon enforced at the Committee, for having them on that capital edifice? For my part, I think it was a happy circumſtance, that there was *no*

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been ſo for ſome time, occaſioned by frequent ſhowers of rain waſhing the pavement in the ſtone gallery. That after the lightning happened, he obſerved a *hole* was made through the dirt, *one quarter of an inch in diameter*, and about *two inches in length.* That the hole was cloſe to the iron. And that upon ſtooping down his head, he perceived a very *diſagreeable ſmell of ſulphur* from the *ſtone*, *dirt*, and *Conductor*; particularly the laſt.

Upon hearing this account, Mr. Delaval and myſelf a few days ago went and examined the Conductors again; but more carefully than before: for upon cauſing the ſtone to be removed which covered the top of the water trunk, we had an opportunity of examining near two feet more of the iron Conductor which points to the water trunk, than we could perceive before this ſtone was removed. When we obſerved that the conducting iron *did not touch the lead.*——We likewiſe obſerved that there was *a very thick coat of ruſt all over that part of the iron, particularly at the end next the lead*, where the water entered the trunk.

As the neceſſity of attending to theſe circumſtances will be obvious to any one who is but in the leaſt degree acquainted with theſe reſearches, *the danger of neglecting them will be ſeen in the ſtrongeſt light by the gentlemen of the Committee*, who recommended the Conductors for the ſecurity of that cathedral.

no point fixed upon the top of the church, to ſolicit a greater quantity of lightning at that moment, than what fell upon the Conductors, circumſtanced as they were; as *that quantity* was great enough to heat ſo conſiderably, a *bar of iron* near *four inches broad*, and about *half an inch thick*.

This powerful effect reminds me of another inſtance ſtill more extraordinary, which happened in *Martinico*, and is related by Capt. Dibden, where a *bar of iron, one inch in diameter*, was, by a violent ſhock of lightning, reduced in one part to the thickneſs *only* of a *ſlender wire*. See Ph. Tr. Vol. 54. p. 251 *.

Since then we are at all times ignorant of the quantity of lightning in the earth and its atmoſphere: and the difference in the effects, between blunted and pointed ends, in cauſing a diſcharge in our electrical experiments, appears to be as 1 to 12. It is eaſy to comprehend the great danger this noble fabric has probably eſcaped, by having no pointed apparatus upon it.

From the above obſervations, I am naturally led to conſider a part of the proceedings of the Committee, reſpecting the magazines at Purfleet: when a certain number of Conductors, with tapering points at the top, were reſolved upon as neceſſary to protect the ſeveral buildings where the powder is depoſited. For it was *agreed* upon, at the ſame meeting, that the Board-houſe, which is a large building for the uſe of the Board Officers, and which ſtands conſiderably higher than the magazines, as was obſerved above, *did not require any point at the top*; becauſe it was apprehended to be *perfectly ſecure*, by reaſon of the copings on the roof, the gutters and pipes to carry off the water, being all of lead: and further, becauſe thoſe pipes communicated with two wells, which always contained water.

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* See the Appendix.

I was not a little ſurprized at this laſt reſolution, which appeared to be ſo *inconſiſtent* with the former. Becauſe if points were neceſſary in one place, they ought to be ſo in another. And on the other hand, if the Board-houſe is ſecure by the leaden accidental Conductors, which have no points, why ought not the magazines to be equally ſecure, when put into the ſame circumſtances?

I therefore enforced the *inconſiſtency* of ſuch a reſolution in the ſtrongeſt terms. Notwithſtanding which, the gentlemen, at that time, thought proper to confirm their reſolution. However, at the next meeting of the Committee, I obſerved that they had been pleaſed, in the mean time, to make an amendment in favour of points for the Board-houſe; which amendment was no ſooner propoſed, than approved of.

Why my obſervation was rejected at the preceding meeting, I muſt leave to the judgment of others. But it certainly carries an appearance, as if *manifeſt contradiction*, upon further reflection, muſt have been the *cauſe* of that alteration.

And I am inclined to believe, from ſome gentlemen of the Committee expreſſing their opinion, in the Committee, " *of its being a matter of mere in-" difference, whether blunted or pointed Conductors*

" *were made uſe of,*" that they have not conſidered this ſubject, with all the attention that ſo important an object deſerves.

For if our experiments ſhew, that points, from the nature of their ſhape, and *other* circumſtances attending them, reſiſt the attacks of this fluid leſs than blunted ends, and that blunted Conductors of proper dimenſions are ſufficient to convey away the lightning *ſafely*, whenever it attacks them, why ſhould we have recourſe to a method, which is at beſt uncertain; and which, ſome time or other, may be productive of the moſt fatal effects? *

But perhaps no argument can be brought with more force againſt the principle of points, than Dr. Franklin's own words, which are publiſhed in his experiments, p. 481: where he declares *poſſitively*— " Buildings, that have their roofs covered with lead, or other metal, and ſpouts of metal continued from the roof into the ground to carry off the water, *are* " *never hurt by lightning*; as whenever it falls on ſuch a building, it paſſes in the metals and not in the walls."

This is the caſe with the *Britiſh Muſeum*, a building alſo of conſiderable conſequence, where there are no other Conductors than what are formed by the copings, gutters, and pipes, which are all of lead, and communicate with the ground. Now it

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* *Points* expoſed for the reception of lightning are likewiſe *ſubject to this material objection:* they are meant to invite, or draw off the lightning *continually*; but we find from experience, that thoſe ſharp points *are extremely ſubject to be melted down and deſtroyed by it*: *they are therefore ſo far rendered uſeleſs and vain*, as no one can exactly ſay *what the duration*, or *what the effects* of any ſtorm of lightning may be.

is from the great quantity of metal contained in the ſeveral pipes, together with the other circumſtances attending them, that I conſidered that building, (in a former paper laid before the Royal Society) as being ſufficiently ſecured from thoſe dangerous effects.

But if any gentleman ſhould be diſpoſed to entertain a doubt about it, or indeed of any other part of my reaſoning on this ſubject, a declaration of thoſe doubts may be attended with good conſequences, as they will neceſſarily open the door to a more minute inveſtigation.

I have now gone through the reaſons which I propoſed to lay before the Royal Society for the *rejecting* of points; and I am very ſorry in the courſe of this letter, to have been under the neceſſity of mentioning any differences in opinion, which paſſed between the members of the Committee, to whom this important matter was referred; I think however, I ſhall ſtand excuſed to the Society and the public, when it appears, as I hope it now ſufficiently does, what my motive has been, namely, to ſtate clearly, and impartially, the objections which I conceived to lie againſt pointed Conductors; and to diſcloſe, *without any reſerve*, the principles on which ſuch objections are grounded.

I am, Sir,
with the greateſt reſpect,
Your moſt obedient,
and moſt humble ſervant,
Benjamin Wilſon.

8 *Dec*: 1772.
Great Ruſſel-Street,
Bloomſbury.

Mr. Delaval, who was one of the Committee, has given me leave to inſert his opinion upon this ſubject; which is this, That he concurs with me in thinking, that ſuch Conductors as are elevated higher than the buildings to which they are applied, or are pointed at the top, are improper and dangerous.

He was deſirous of delivering his opinion at the Committee; but as the meetings of it were held in the Summer only, his abſence from London prevented his attendance.

Read at the Royal Society the
10th of December, 1772.

A LETTER

From EDWARD HUSSEY DELAVAL, Eſq; F.R.S. to Mr. WILSON, F.R.S. &c.

SIR,

FROM the Report of the Committee appointed by the Royal Society, it appears that pointed Conductors were recommended to ſecure the magazine at Purfleet, from the effects of lightning: But as I find, from your Diſſent, which accompanies that Report, that in conformity to what you had formerly advanced, you apprehend that ſuch Conductors are dangerous; and as my abſence from town prevented my attendance on the meetings of the Committee, which were held during the vacation, I think it incumbent upon me to comply with your deſire of giving my opinion on this ſubject, and the reaſons on which it is founded.

The queſtion ſeems to amount to no more than this, Whether it be proper to uſe pointed Conductors, which invite or facilitate the entrance of lightning into buildings, in preference to blunted ones, which have not the like power of ſoliciting it?

I believe every one will now admit, that pointed Conductors are indued with a power of drawing lightning from the clouds; as it was from this theory that the firſt experiments were made, and the ſucceeding ones have conſtantly confirmed it.

If it is the opinion of any one, that the invitation of ſo formidable an enemy is deſirable, it muſt, I imagine, be founded on a ſuppoſition, that all the electrical contents of the impendent cloud, can be completely and inſtantaneouſly carried off through ſo narrow a channel, ſo as to be no longer capable of acting upon the intermediate parts of the building.

But I believe this ſuppoſition will not appear agreeable either to reaſon or experience, when we conſider that clouds of a dimenſion equal (as Dr. Franklin judiciouſly ſuppoſes) to * ten thouſand acres, are frequently fully charged with the matter of lightning; and that although lightning † "ſtrikes "the higheſt and moſt pointed objects in its way, "preferably to others, as high hills, and trees, "towers ſpires, maſts of ſhips, &c", which therefore muſt be looked upon as Conductors; yet in this city, notwithſtanding no place furniſhes a greater number of theſe elevated and pointed objects, the collective power of all of them, in draining the impendent clouds, is conſtantly found inſufficient to defend even the *loweſt parts of the city from being injured.*

This appears, not to mention other inſtances, from the effects of the lightning in Eſſex-ſtreet on June 18, 1764, at the ſame time that St. Bride's church was ſo greatly damaged.

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* Franklin's Exp. p. 65.

† Prieſtley Hiſt. Elec. p. 175.

Nor were the Conductors of St. Paul's church able to defend the chapel in Tottenham Court Road, which appears to have been ſtruck nearly, if not exactly, at the ſame time with that cathedral, on March 22, 1772.

If the united power of ſo many Conductors, as are contained in and about this large city, are inſufficient to deprive the impending cloud of its contents, how then can we expect ſo great an effect from ſo narrow a channel as one or two ſmall Conductors can afford.

If this be rightly ſtated, the intention of draining the contents of ſuch immenſe bodies by ſuch ſmall conveyances, is entirely fruſtrated; and we can no longer aſſign that, as a reaſon for inviting the lightning from them into ſuch buildings as we mean to ſecure.

It is true, that a blunted Conductor will receive a ſpark from a body charged with the electric fluid at a greater diſtance than a pointed one will; but, on the other hand, a *pointed* one will receive the *greater quantity, and with a greater facility*: the *ſpark*, which is viſible when the blunt body is uſed, is a ſign that the electric matter finds a *difficulty in entering* that Conductor.

No argument can be drawn from hence in favour of points, the object in view not being to guard againſt the *appearance* of the lightning, on it's *entering the top of* the Conductor, but to prevent the damage which will ariſe from *too great a quantity after it has entered* the Conductor, or any other part of the building; and it cannot be denied, that pointed and elevated rods of metal will receive from the clouds a greater quantity, and with leſs reſiſtance, than ſuch as are blunted.

When a ſmall wire, with its ends blunted, is interpoſed between the inſide and the outſide of a large jar properly charged, without touching either of them, a ſpark will be ſeen at each end of it, and it will, by the paſſage of the electric fluid through it, be either melted or become red hot. But if a needle be joined to the end of the wire, which is neareſt to the inſide of the jar, and be brought into contact with it, *no ſpark* is ſeen *at the entrance* of the fluid into the wire, yet the *ſame effects* are produced, as when the ſpark was viſible.—

Nor will the pointed Conductors have any advantage over blunted ones, in drawing off the charge *gradually*, if they perform that operation *ſuddenly*, according to the ingenious experiment of Dr. Franklin, made with a prime Conductor ten feet in length, and one in diameter; which gave riſe to his theory of drawing the lightning from the clouds. As it is an experiment very applicable to this queſtion, I ſhall here relate it in his words: "Let a perſon, "ſtanding on the floor, preſent the point of a needle "at twelve or more inches diſtance from it; and "while the needle is ſo preſented, the Conductor "cannot be charged, the point drawing off the fire "as faſt as it is thrown on by the electrical globe. "Let it be charged, and then preſent the point at "the ſame diſtance, and it will *ſuddenly* be diſ"charged."

* Dr. Franklin, in another part, gives us the following experiment: "† An eye ſo ſituated as to

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* Franklin's Exp. p. 63.

† Ib. p. 126.

"view horizontally the under ſide of a thunder-
"cloud, will ſee it very ragged, with a number of
"ſeparate fragments, or petty clouds, one under
"another, the loweſt ſometimes not far from the
"earth. Theſe, as ſo many ſtepping-ſtones, aſſiſt
"in conducting a ſtroke between the cloud and a
"building. To repreſent theſe by an experiment;
"take two or three locks of fine looſe cotton, connect
"one of them with the prime Conductor by a fine
"thread of two inches, (which may be ſpun out of
"the ſame lock by the fingers) another to that, and
"the third to the ſecond by like threads — Turn
"the globe, and you will ſee theſe locks extend
"themſelves towards the table, (as the lower ſmall
"clouds do towards the earth) being attracted by
"it; but on preſenting a ſharp point erect under
"the loweſt, it will ſhrink up to the ſecond, the
"ſecond to the firſt, and all together to the prime
"Conductor, where they will continue as long as
"the point continues under them. May not, in
"like manner, the ſmall electriſed clouds, whoſe
"equilibrium with the earth is ſoon reſtored by the
"point, riſe up to the main body, and by that
"means occaſion ſo large a vacancy, as that the
"grand cloud cannot ſtrike in that place?"

If the clouds ever happen to be circumſtanced, as the locks of cotton and the prime Conductor are here deſcribed to be, the effects of the pointed Conductors upon them will probably be ſimilar to thoſe produced on the cotton in the experiment; one circumſtance however in the experiment ſeems materially to differ from the great proceſs of nature, in imitation of which it is made.—*The large or principal cloud* is, in this experiment, repreſented by the *prime Conductor*, which is a ſolid body having a *fixed* place in the apparatus, and conſequently *incapable of moving* towards the point, as the looſe locks of cotton do: But the *clouds* are compoſed of a *fluid* matter, *moving with the utmoſt facility* in another fluid ſubſtance, viz. the air, and are ſubject *to change their forms and ſituations* in the atmoſphere with great rapidity, accordingly as they are affected by different cauſes: It does not therefore appear from any part of the experiment, that when the lower and more detached clouds have given out their electric contents to the pointed Conductors, the upper and principal cloud will not extend itſelf towards them, in order to diſcharge its electric contents into them, according to the conſtant law, that bodies containing an exceſs of the electric fluid, whenever they are at liberty to move freely, will accede to other bodies in which there is a comparative deficiency of the ſame fluid.

And indeed, if we were certain that the effect of pointed Conductors was ſimilar to what is ſeen in the experiment, when the clouds happen to impend over buildings in that detached form; yet clouds often are in other forms, ſo that they are differently circumſtanced, and then no ſuch advantage can be ſuppoſed to enſue.

Clouds of an immenſe ſize are often in one united maſs; buildings, and frequently whole cities are totally immerged in ſuch clouds, whilſt they are replete with lightning. Various inſtances of this kind are related by the learned Beccaria, and I have myſelf ſeen many ſuch. On the 22d of March, 1772, I obſerved from my window, which is ſituated on the weſt ſide of the Thames, a large thunder cloud, which extended itſelf over the hills in Surry, ſouth of London; the neareſt part appearing about ſix miles from thence; at the ſame time the ſky between that cloud and London was extremely clear, but in a few minutes after my obſerving the cloud at that diſtance, it approached the city, which immediately afterwards became immerged in it. At the ſame time there fell a heavy rain, and lightning appeared to proceed from the ſouth-eaſt towards the town. During the time of this ſtorm I continued to obſerve, from my window, St. Paul's church, but could not perceive that the lightning directed itſelf particularly towards that building, which, as well as the reſt of the town, was entirely ſurrounded by the cloud. — I ſhall hereafter mention the effects which were then produced on the Conductors of that church. If Conductors were capable of exhauſting clouds charged with lightning of their contents, *that* would have taken place in the ſtorm I have here mentioned; but notwithſtanding the numerous Conductors through which part of the lightning was conſtantly paſſing, yet the flaſhes continued to ſucceed each other with undiminiſhed force for a conſiderable time, as they frequently do in thunder-ſtorms, ſo as to deprive us of all hopes of exhauſting the lightning either contained in ſuch immenſe maſſes, or paſſing through them to or from the earth and the buildings, and other objects on its ſurface.

Dr. Prieſtley obſerves from Beccaria, that he found*, " from his obſervations of the lightning " abroad, and his apparatus within, that the *quantity* of electric matter, in an uſual ſtorm of thunder, is *almoſt inconceivably great*, conſidering how " many *pointed* bodies, as trees, ſpires, &c. *are perpetually drawing it off*, and what a prodigious " quantity is repeatedly diſcharged to or from the " earth.

" Conſidering the *vaſt quantity* of electric fire " that appears in the *moſt ſimple* thunder ſtorms, he " thinks it impoſſible that any cloud, or number of " clouds, ſhould ever contain it all, ſo as either to " diſcharge or receive it.—Beſides, during the progreſs and increaſe of the ſtorm, *though the lightning* " *frequently ſtruck to the earth*, *the ſame clouds were* " *the next moment ready to make a ſtill greater diſcharge*, and his apparatus continued to be as much " affected as ever."

I think it evidently appears from theſe facts, that the quantity of lightning, which can be drawn from large thunder clouds by means of Conductors, is ſo very ſmall a part of the whole contained in them, that any attempt to exhauſt them muſt be looked upon as altogether vain.

This being eſtabliſhed, it will be neceſſary, in the next place, to conſider the manner in which lightning affects Conductors, even thoſe which are conſtructed with the greateſt care.

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* Prieſtley's Hiſt. Electric. p. 344.

In anſwer to your paper againſt pointed Conductors, publiſhed in the Philoſ. Tranſ. Ann. 1764, Dr. * Prieſtley quotes from Beccaria the following paſſage; " that no metallic apparatus can attract more " lightning than it can conduct." This however is directly contrary to experience, for metallic bodies, not properly communicating with the earth, are frequently found to receive (or attract) a ſufficient quantity of lightning to heat, melt, or even diſſipate them; thus, ſwords, watches, &c. and metallic parts of buildings, are often injured, though they certainly receive a leſs quantity of lightning than bodies which communicate with the earth, the reſiſtance in the latter caſe being leſs.

Whenever a metallic Conductor is interpoſed between any two bodies, differing greatly from each other in their quantities of the electric fluid, it will paſs with great violence through the Conductor, in order to produce an equilibrium: If the metallic rods are not thick enough to conduct this quantity properly, they will, according to their proportional deficiency, either be deſtroyed, or will communicate violent effects to ſuch bodies as are in contact with, or near, them.

The greateſt quantity of the fluid hitherto collected in electrical experiments is infinitely leſs than that which paſſes from thunder clouds to the earth, and yet a quantity, far ſhort of what may be ſo obtained, is ſufficient to melt ſmall wires, although as free a channel is given to it, as the ſmallneſs of the wire can afford.—When the wire is too large to be melted:

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* Prieſtley Hiſt. Elect. p. 406.

melted by the paſſage of the fluid through it, but too ſmall to convey it with eaſe, very violent effects are produced on ſuch bodies as are in contact with it, or placed near it; for ſuch bodies will be torn to pieces, burnt, or otherwiſe violently acted upon.

I ſhall here quote from Dr. Prieſtley ſome experiments which he mentions on this occaſion, relative to what he calls, the *lateral force of electric exploſions*,* which force was, I believe, firſt diſcovered by you, and publiſhed in your Treatiſe on Electricity, in the year 1750.† The *effects of this lateral exploſion* he thus deſcribes: "I laid a green leaf upon "the palm of my hand, intending to make the ex-"ploſion paſs over the leaf; but the leaf was *burſt* "and *torn to pieces*, and the exploſion paſſing *over* "my hand, gave it a *violent jar*, the effects of "which remained in a kind of tingling for ſome "time.

"Laſtly, in order to judge the moſt perfectly of "this force, I laid a chain, communicating with "the outſide of the battery, upon my naked arm "above the wriſt, and bringing the diſcharging rod "near the fleſh, within about two inches and a "half of the chain, I made the exploſion paſs over "that quantity of the ſurface of the ſkin."

The effects of this exploſion were, "the hairs "upon the ſkin were all *ſinged, and curled up along* "*the whole path of the exploſion, and for the ſpace of* "*about an inch on each ſide of it*; alſo the papillæ "pyramidales of the ſkin were raiſed as when a

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* Prieſtley's Hiſt. Elec. addit. p. 44.

† Vide p. 89, and the Plate III. fig. 9.

" perſon is ſhivering with cold. *This was alſo the* " *caſe in every part of the arm which the chain touched,* " *and even that part of it which was not in the circuit.* " Both the path of the exploſion, and the place on " which the chain had lain, had a redneſs, which " remained till the next day. Sometimes the fleſh " has contracted a blackneſs by this experiment, " which has remained a few hours."

In electrical experiments the common, and moſt commodious, method of obtaining a large exceſs of the electric fluid in one place, and a large defect of it in another, is by the Leyden Experiment; but an equal exceſs and defect may be obtained in two ſeparate non electric bodies if they are ſufficiently large, and one of them be electrified poſitively the other negatively. And by ſuch an experiment we may ſuddenly convey the contents of the body charged poſitively, into that which is electrified negatively, and ſo produce, in the Conductor, &c. effects equal to thoſe of the Leyden Experiment.

But tho' the bulk of the bodies, required to perform ſuch an experiment, renders it inconvenient to us, the proceſs is ſuch as nature frequently performs, with this difference only, that the quantity often ready to be diſcharged from the clouds into the earth, through metallic Conductors or parts of buildings, is infinitely greater in proportion to thoſe Conductors, than the largeſt charges of our apparatus are to the ſmall wires which they are capable of affecting.

Let us ſuppoſe that ſeveral large metallic rods were placed as Conductors, to a magazine of gunpowder,

powder, and that the lightning was diſcharged from the clouds to the earth through them, in a quantity proportionably greater than that which paſſed thro' the wire and chain in Dr. Prieſtley's experiment, which is an imitation in miniature of the infinitely greater quantities of lightning diſcharged from the clouds through Conductors: would not the effects of tearing to pieces and burning have been produced by the Conductors in the magazine, in the ſame manner, and from the *ſame cauſes*, that affected the green leaf, hair, and ſkin, in the experiment performed in miniature? and would not the lateral force of this natural diſcharge extend itſelf to a proportionably greater diſtance from ſuch Conductors, to ſeveral feet diſtance quite round them, if an overcharge of lightning paſſed through them?

Nor need we rely on reaſonings taken from electrical experiments only.

If Conductors, purpoſely placed in buildings, were with care examined after every thunder ſtorm, and authentic accounts of them given to the public, ſtill greater lights might probably be thrown upon this matter.

The effects produced on the Conductors of St. Paul's, by the firſt conſiderable ſtorm of lightning, which happened after they had been placed there, with the utmoſt care and conſideration, by the committee appointed by the Royal Society, at the deſire of the dean and chapter of that church, afford a remarkable inſtance, that ſuch a *lateral force* takes place in the *largeſt Conductors* which have as yet been employed.

The Conductors of St. Paul's were examined with great attention by Mr. Richard Gould, one of the vergers of that cathedral, on the 23d of March 1772, the day after the lightning had paſſed through them: As the letter he wrote to you contains ſome intereſting and curious facts, of the truth of which we were witneſſes; and as this paper, together with others on the ſame ſubject, though laid before the Royal Society, have not been thought proper to be publiſhed, it is neceſſary for me to mention here ſome of thoſe facts, as they greatly illuſtrate what I have advanced in regard to the danger from a lateral force in particular ſituations.

Some of theſe Conductors appeared to have undergone a conſiderable violence by the paſſage of the lightning through them, inſomuch that a thick ruſt, which was formed on their ſurface, was, by the lateral force, *beaten off, and removed to ſome diſtance* from them: The iron bars themſelves had, for many *feet*, the appearance of having been *heated red hot*, reſembling iron newly taken from a ſmith's forge: in other parts, the iron, as well as the ſtones near it, *was blackened by ſmoke.* ——————

Theſe bars ſeem to have undergone nearly the ſame violence as the wire and chain in Dr. Prieſtley's experiments, which I have before mentioned, with this difference only, that as the ſize of the Conductors greatly exceed that of the wire and chain, ſo did the quantity of electric fluid, which paſſed through them. It is probable that a greater thunder ſtorm may at ſome future time produce ſtill more violent effects on them: thoſe already obſerved would have proved fatal, had the bars been placed in a magazine of gunpowder, inſtead of being contiguous to ſtone or other incombuſtible materials.

I have been informed that there are ſome curious particulars, relative to this ſubject, contained in a paper lately communicated in writing to the Royal Society, at its deſire, by Dr. W. Hunter a reſpectable member of it, but as it is not ordered to be printed, and as on ſearching the journals of the Society, I find that no minute has been made of this paper, I cannot be ſufficiently informed of the particulars to refer to them.

I cannot help regretting that ſuch accounts are not thought worthy of publication, as it is only from a ſufficient number of well atteſted facts, that this part of ſcience, hitherto ſo little underſtood, can have ſufficient light thrown upon it.

It appears evidently, that lightning produces very violent effects in paſſing through even thoſe Conductors, which are conſtructed with the greateſt caution, and which are contrived to carry it off without inviting it.—And it muſt be admitted that ſuch conductors, if pointed at the top or elevated above the building, would facilitate the entrance of a much greater quantity, and conſequently more violent effects would thereby be produced.

It alſo appears that the largeſt metallic rods, even when pointed, are incapable of exhauſting large clouds of their electrical contents.

But although our Conductors are inadequate to ſo great a power, as that which is neceſſary to exhauſt clouds of an immenſe ſize; yet they may be applied with great probability of ſucceſs, to carry off with ſafety as much lightning as may at any given time be contained in the metallic parts of a building, provided a complete communication be formed between them and ſufficiently large Conductors.

In a building, thoſe parts which are capable of being charged with lightning, may be *meaſured or eſtimated*, and conſequently ſuch Conductors may be applied to them, as, from their *ſize and conſtruction*, are adapted to carry off that *given quantity:* but as we *cannot meaſure or eſtimate* the quantity of lightning, which may at any given time be contained *in the clouds*; ſo it is impoſſible to determine what quantity will, at any time, paſs through ſuch Conductors as are pointed and elevated above buildings, on purpoſe to facilitate its entrance.

I cannot determine what degree of ſucceſs has attended the uſe of pointed and elevated Conductors, during the ſmall number of years that they have been erected; as the only particular accounts of them, which I have met with in the publications of Dr. Franklin, as well as in the papers received by the Royal Society and others, relate merely to ſuch Conductors as have been *unſucceſsful, their points having been melted,* and the houſes, &c. to which they were applied, having *been injured:* —— But it is with great pleaſure that I find, from a paſſage in Dr. Franklin's letters, that he agrees with us in opinion, that Conductors, which are *not pointed at the top*, nor *elevated above the roof*, and which are *ſufficiently large*, and properly connected with each other, have *without any exception* been conſtantly found ſuccefsful for many ages paſt: The following is the paſſage which I refer to: "Buildings that "have their roofs covered with lead, or other *me-* "*tal*, and *ſpouts of metal* continued from the roof "into the ground to carry off the water, are *never* "*hurt* by lightning, as whenever it falls on *ſuch a* "*building*, it paſſes in the metals and not in the "walls." *

I cannot help expreſſing my regret, that our concluſions differ from thoſe of Dr. Franklin, and others who have wrote on this ſubject, though drawn principally from the ſame experiments. I have in the courſe of this letter fully explained the reaſons on which my opinion is grounded; but ſhall attend with the greateſt deference to ſuch arguments as may be brought againſt it.

I am,
Sir,
Your ſincere friend,
and humble ſervant,

Edward Huſſey Delaval.

Cotton Garden,
Weſtminſter,
Feb. 20, 1773.

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* Franklin's lett. p. 481.

APPENDIX.

The very extraordinary effects of lightning upon the *iron bar* in *Martinico*, (mentioned in page 15.) being attended with a remarkable circumſtance, it may be worth our while to make ſome obſervations upon it.

THIS bar was not only *reduced* to the *thickneſs of a ſlender wire* at the end next the wall, but, what deſerves more particular attention, there was *a gradual diminution* to that part of the bar for more than *one foot*, as *Captain Dibden* informed me.

This *ſingular effect*, I apprehend, depended upon a *very great accumulation of the lightning* at that inſtant in the bar; which was cauſed by a *certain force that oppoſed its paſſage*, proceeding from the nature of the wall *where the iron terminated*, and where the *greateſt accumulation* of that fluid muſt neceſſarily have happened; as muſt *the leaſt accumulation* at the *greateſt diſtance* from that end. Hence we ſee the reaſon, why the effect upon the iron ought to be leſs and leſs, in proportion to the diſtance from the wall.

For wherever there is an accumulation of the electric fluid, there is always a force acting againſt it, to *occaſion that effect*; which is alſo true in regard to lightning. And that an accumulation does take place, in conſequence of a force which is exerted *in* all bodies, or *at* their ſurfaces, may be collected from *every electrical experiment*: but in none more clearly, than where a great quantity of this fluid is diſcharged with violence through diſtinct pieces of metal in particular circumſtances *.

For if the experiment is made with a chain, properly ſuſpended, thoſe parts of the links that appear to be in contact with each other, are inſtantly melted by the violent action of the fluid, in its endeavouring to paſs from one link to the other, while the other parts remain firm and entire.

Similar to the above appearances, are thoſe, where rods, or other ſmall pieces of metal, lie ſo near to each other, that they are commonly ſaid to touch. For at thoſe parts, where there is an imperfect contact after the experiment is over, we frequently obſerve appearances of their having been melted: and, in ſome caſes we are able to trace the marks of a more violent effect: ſuch as a ſudden diſſipation of ſome part of the metal.

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* Among many inſtances, of this kind, is one which happened in March laſt, at a chapel in *Tottenham Court road*, on the ſame day and hour, (if not exactly at the ſame moment) that St. Paul's church was ſtruck; the account of which was given to the Royal Society by Mr. Henley.

There is one obſervation that perhaps is not of the leaſt importance; it is this, I am very apprehenſive, that unleſs the *utmoſt attention is paid to this reſiſting principle in all caſes*, the concluſions drawn from our experiments cannot always be depended upon.

What I mean by this *reſiſting force*, that acts ſo powerfully againſt the attacks of lightning, and the electric fluid, is explained in the experiments and obſervations I made many years ago; and which were afterwards republiſhed in a more ſyſtematical manner, with additional obſervations by Dr. Hoadly and myſelf. It may not however be improper, in this Appendix, to inſert ſome of them; and likewiſe ſome obſervations of the like nature, which I made, and publiſhed in a letter to *Epinus*, profeſſor at Peterſbourgh: as I hope they will contribute to make the philoſophical part of this publication better underſtood, by thoſe who may have inclination and leizure to conſider them.

The late *event*, which happened to the Conductors in St. Paul's cathedral, affords us a remarkable inſtance of the powerful effects of lightning, in conſequence of the above reſiſting principle.

I choſe therefore to hang that fact out, as the moſt extraordinary, and capital experiment produced by the power of lightning, which has hitherto come to our knowledge: and I make no doubt, but that the ableſt electricians in Europe will entertain the ſame opinion: when they conſider the *quantity of metal*

metal heated in that experiment: *the particular ſituations of that quantity*, compared with *the nature of the circumſtances that oppoſed the paſſage of the lightning at thoſe parts only*, which have been already deſcribed.

What ſhall we ſay then to papers, containing ſuch extraordinary facts, being rejected, and withheld from publication, by the influence of any?—

I cannot account for it any otherwiſe, than that it contradicted certain doctrines, which, of late years, have perhaps been too implicitly ſubſcribed to.

The fact itſelf indeed, was little attended to at the time, except by Mr. Delaval and myſelf, who, on receiving information of thoſe effects from Mr. Richard Gould, examined into the particulars within a week after the ſtorm happened.

Some other gentlemen of the Royal Society, about three weeks after the event, viſited thoſe Conductors alſo. But as, during that interval, great quantities of rain had fallen for many days together, and the iron part of the Conductors were expoſed to the weather, the greateſt part of the ruſt, which was thrown off, and the black appearances upon the ſtone, &c. muſt have been waſhed away: and the ſurface of the iron itſelf muſt alſo have undergone ſome alteration, from the action of the air and water upon it, by forming afreſh another, though thinner, coat of ruſt.

This remark is apprehended to be the more neceſſary, becauſe I am informed, that thoſe gentlemen,

men, who viſited the church at that period of time, did not find the appearances ſo ſtrong as we did. But however this may be, I can ſafely affirm, that even after an interval of nine months at leaſt from the time the ſtorm happened, the parts of the large iron bars, which were affected by the lightning, as hath been deſcribed, were conſpicuouſly different from the other parts of the ſame bars, which did not ſuffer that violence.

Hoadly and Wilſon, p. 53, &c. *

THUS have we ſeen, that the variety in the reſiſtances made by different bodies to being electrified, have led us into the knowledge why bodies act ſo differently in one ſituation, from what they do in another, according to the nature, ſhape, and quantity of the bodies they are contiguous to

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This our ſucceſs in purſuing this train of reaſoning is ſurely ſufficient to encourage us to enquire farther, where this reſiſtance is exerted, and from what power within the body it ariſes.

Now from our knowing by experiment, that every body more or leſs reſiſts being electrified; which is now allowed to mean, that every body reſiſts the paſſage of the electrical fluid, either *into* them, or *out* of them, though ſome do it with a greater force than others, we may very reaſonably conclude, that when the fluid is endeavouring to get into any body, the reſiſtance it meets with is exerted at that particular ſurface, at which the attack is made: and when this fluid is endeavouring to get out of any body, the reſiſtance it meets with is exerted at all its internal ſurfaces at once; and if the force with which this fluid endeavours to get in, or out, is ſuperior to the force which endeavours to keep it out or in, at any place, or phyſical point of any of its ſurfaces, it muſt make its way more eaſily there, and conſequently will always paſs that way either in or out.

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* Obſervations on a ſeries of Electrical Experiments, printed for Payne 1756.

And there is an appearance in glaſs that is exactly analogous to this, with regard to the reflection of the rays of light; by which it is evident, that a pane of glaſs reſiſts the entrance of light in at one ſurface; and when it has got in, it as ſtrongly reſiſts its going out at the oppoſite ſurface, becauſe at both theſe ſurfaces it reflects or drives off great numbers of rays, that without ſuch reſiſtance would have paſſed readily through the pane of glaſs.

It is likewiſe known, that the rays reflected thus back into the glaſs, upon their endeavour to get out, and returned again to the firſt ſurface through which they had once got, meet again with an equal reſiſtance there to their paſſing out, and are many of them reflected into the glaſs again.

It is ſhewn farther by Sir Iſaac Newton, that this force begins to exert itſelf on the rays of light *before they arrive into contact with either of theſe ſurfaces.*

And hence we have reaſon to believe, that the the reſiſtance we have experimentally ſhewn to be made by all bodies againſt being electrified either *plus* or *minus*, is of the ſame nature with that which not only prevents the entrance and exit of the rays of light in glaſs, but throws them off with the ſame velocity, great as it is, with which they endeavour to get into it, or out of it; and therefore moſt probably ariſes from the ſame cauſe.

And conſequently, that this reſiſtance in bodies to being electrified, is exerted as the other is, *before the electrical fluid comes actually in contact with the ſurface of any body it endeavours to electrify.*

The experiments therefore in Sir Iſaac's Optics ſerve greatly to confirm the opinion we have endeavoured to eſtabliſh by electrical experiments, that every body reſiſts the entrance and exit of this electric fluid; and that this *reſiſtance* is exerted at *ſome diſtance before the fluid* that endeavours either to get in, or out, *arrives at the ſurface* where the endeavour is made.

Our next enquiry is, whence this power ariſes, that is thus exerted at the ſurfaces of bodies.

In order to anſwer this; we have ſeen, that whilſt any body continues to be ſenſibly, or perceptibly, electrified, whether it be *plus* or *minus*, in any of the experiments made on them by art, there is an *atmoſphere of the ſame kind of fluid*, which naturally belongs to, and is formed *round them*, *ſufficiently ſtrong to balance every power that endeavours to electrify them above a certain degree:* otherwiſe they might be electrified more and more *without limit.*

This atmoſphere therefore, thus ſurrounding the ſurface of bodies, when artificial force electrifies them, is what reſiſts their being electrified more; and when it abſolutely prevents it, muſt be equally denſe and powerful with that electrical fluid that flows from the excited tube or machine, which endeavours to force its way through theſe atmoſpheres into the bodies, in order to electrify them more.

In the ordinary and quiet manner in which the imperceptible works of the author of nature are carried on among the component particles of the groſs bodies on or near the ſurface of the earth; this ſubtile, active, electrical fluid, which not only ſurrounds each groſs body, but pervading its pores, ſurrounds every component particle of it, where it is not in abſolute contact with its neighbouring component particle; this active fluid, I ſay, cannot be idle, but muſt be in action, though that action be imperceptible to our ſenſes: and it muſt, in an imperceptible degree, be varying its condition in all the parts of bodies whatever, i. e. in our preſent way of expreſſing ourſelves, be electrifying them *plus* or *minus*, though not ſo forcibly as to give ſenſible ſigns of it *.

We may therefore not unreaſonably conclude, that all bodies whatever, in their natural ſituation, and

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* As theſe terms may not be underſtood by every one, it may be proper to obſerve, that there is a certain quantity of this fluid belonging to all bodies naturally; and whenever we *increaſe* that quantity in any ſubſtance by art, that body is ſaid to be electrified *plus*. On the contrary, when we *reduce* the natural quantity of this fluid in any ſubſtance by art, that body is ſaid to be electrified *minus*.

all the component particles, have ſurrounding their ſurfaces, not in abſolute contact with other ſurfaces, an imperceptible atmoſphere of elaſtic particles ſufficient to balance the ſmaller force with which they are attacked ; every way ſimilar to the perceptible atmoſpheres, at the ſurfaces of bodies electrified forcibly, either by art, or the violent exploſions in nature.

In theſe atmoſpheres, which ſurround the ſurfaces of all bodies, is placed the power, which occaſions the reſiſtance found experimentally to be made againſt thoſe bodies being electrified to a higher degree than they are naturally, before we attempt to electrify them perceptibly to our ſenſes : and the power is the elaſticity of this ſubtile electrical fluid, every where diſperſed indeed, where groſs bodies are out of the way, but likewiſe confined within bodies differently, according to their different ſituations and neighbourhood to other bodies.

And theſe atmoſpheres may be encreaſed, or diminiſhed, to a certain degree, many ways by art ; and when this is done with violence, the natural contexture of the bodies is altered in proportion to the violence.

But to make it ſtill plainer that the reſiſtance to electrification is made at the ſurfaces of bodies, I will ſhew in the following very curious experiments, that the electrical fluid, in paſſing from one body to another will always take that way, in which it meets with the feweſt ſurfaces to break through.

Let a *Leyden* bottle, that has a hook in its coating, be electrified and ſet down on glaſs, and left to itſelf. Let one end of a clean chain (ſuch an one as is commonly uſed for a jack, but rather lighter) be fixed on to the hook in the coating; and let a perſon graſp the coating of the bottle with one hand, and with the other hand bring the other end of the chain, and his finger and thumb that holds it, at the ſame time into contact with the wire of the bottle. Here then are two ways offered for the electrical fluid to paſs from the wire to the coating, either through the perſon or the chain: and if the links of the chain hang looſely on one another, it paſſes through the perſon, and he is ſhocked very nearly as much as if the chain was not there. But if the chain be ſtretched by any contrivance, ſo that its links are all brought nearer into contact with each other, the fluid will paſs through the chain, and the perſon will feel no ſhock at all: and this will be the caſe, let the chain be ever ſo long.

Whence it follows, that the electric fluid does not always paſs from one body to another by the ſhorteſt way, but, on the contrary, it will go about, and paſs that way in which it meets with *leaſt reſiſtance.*

Now if the chain alone forms the communication between the wire and the coating of the bottle, and it is ſpread ſo on a table, that the links of it ſcarce ſeem to touch one another, there will not only be a ſpark ſeen on the approach of the end of the chain to the wire of the bottle; but a number of them will appear very viſibly when the experiment is made in the dark, *viz.* at every place where the links do not abſolutely touch one another. But when the chain is ſtretched tight enough to have every link brought nearer into contact with its neighbouring links, there appears but one ſpark on bringing the end of the chain to the wire of the bottle; the whole chain then forming one continued metal nearly.

By the appearance of theſe ſparks, or their non-appearance, we judge whether the electrical fluid paſſes through the chain or no.

Now in theſe experiments we have ſeen, that when the links of the chain were looſe, the perſon was ſhocked, and the fluid paſſed through him; and that it did not paſs likewiſe through the chain, appears from the experiment, becauſe no ſuch ſparks appear between the links.

Whence we may fairly conclude, that the reſiſtance made to the paſſage of the electrical fluid through the chain, ariſes from the *ſum of the reſiſtances* at the different ſurfaces of the links, it was to break it's way through in paſſing through the chain. Becauſe when the links were forced nearer into contact with each other, and ſo the whole chain was made, as it were, one continued metal, this reſiſtance is entirely taken off, the perſon is not at all affected on the diſcharge of the bottle, nor do any ſparks appear between the links.

Now if the experiment be repeated in the following manner, this conſequence will be ſtill plainer. Let one end of a wire, even many times longer than the chain, be faſtened to the hook at the coating of the bottle, as well as the chain, and let a perſon graſping the bottle, as before, bring the other ends of both the wire and the chain into contact with the wire of the bottle, and let the links of the chain lie looſe on the table; or let the chain not be ſtretched.

Here are plainly three ways the electrical fluid may paſs on the diſcharge of the bottle, through the perſon, through the chain, or through the wire: and the event of the experiment ſhows, that it does not paſs through the perſon, becauſe he feels no ſhock; and that it does not paſs through the chain, becauſe no ſparks are ſeen between the links; and therefore that it paſſes through the wire, where it muſt meet with but one ſurface to break through, viz. the ſurface at the end that is brought to the wire of the bottle, the other end of it being ſuppoſed to be in contact with the hook at the coating of the bottle.

I ſhall obſerve by the by, that no one, who had not made the experiment, would imagine with how much force the chain muſt be ſtretched before the experiment will anſwer, and the electrical fluid paſs through it without producing a ſpark at any of the links, i. e. before the links can be brought ſufficiently near in point of contact with each other: which one would naturally think their weight alone would be ſufficient to do.

But it appears that their weight will not do this, but that ſome additional force, independent of themſelves, or their weight, is required to bring them into a *nearer contact*. †

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† Mr. Delaval made an experiment, which is very much to the preſent purpoſe. It is publiſhed along with many other very curious ones,

THESE laſt experiments are a ſtrong confirmation of the *reſiſting principle.* However, we will endeavour to illuſtrate it farther by the following argument, which is founded upon ſome obſervations of Sir Iſaac Newton's, reſpecting the preſſure of convex-glaſſes; and which I have taken from the letter to *Epinus,* mentioned in the 38th page.

When a *bladder* is well blown up, and ſecured properly, it will yield or give way, and change its form in that part againſt which any given preſſure is exerted. And upon removing the preſſure, the bladder will immediately recover its firſt form.

This yielding or giving way of the form, and then afterwards recovering it, proves an elaſtic ſubſtance exiſting within the bladder, and between the two ſides where the preſſure is employed.

In like manner, when two glaſs priſms, or the object glaſſes of two long teleſcopes preſs upon each other with their own weight only, philoſophers know, by the phœnomena of light, that they do not touch: and that there muſt be ſomething between the glaſſes to keep them at a diſtance. They alſo know, by the like phœnomena, that more preſſing is

ones, upon the convertability of conducting ſubſtances into non-Conductors of the electric fluid, in the Phil. Tranſ. Vol. 51. p. 87.

" Having dried a Piece of Portland ſtone, I found it conducted
" perfectly well; but upon powdering and ſealing it up in a glaſs
" tube, in which was a wire at each end) it became a perfect re-
" ſiſter or non-conductor like the *metallic calces*; which ſeems to ſhew, that the reſiſtance to the paſſage of the electric fluid may be increaſed, by increaſing the number of ſurfaces.

is required to bring them nearer to a contact; and that when the preſſure is removed, they immediately recover their firſt diſtance.

Now this yielding, or giving way, and the recovery of the diſtance between the glaſſes, proves the exiſtence of ſome *elaſtic ſubſtance* between them reſpectively. Since we find the effects of applying, and removing the preſſure, exactly ſimilar to the caſe with the bladder.

THIS is the *medium* then which gives riſe to the reſiſtance found in electric experiments.

For when a quantity of the electric fluid is forced into the apparatus, which ſupports the two balls, (mentioned in the preceding experiments) we ſhould, from its elaſtic principle, expect it to paſs out again immediately: whereas the fact is, that it paſſes out by ſlow degrees; and takes a conſiderable time in evacuating the apparatus. Some *power* therefore muſt hinder the fluid, at leaſt, in ſome meaſure, from eſcaping: and that power therefore muſt be exerted at, or near, the ſurface of the body.

To ſay it is forced in, and *detained*, by an *attraction of the body*, will not anſwer the purpoſe; *for the power which is ſuppoſed to draw the fluid into it*, muſt certainly *be ſufficient to hinder it from paſſing out*. Now, by the experiment, the fluid does paſs out, though ſlowly: this *power* therefore which reſiſts its paſſing out, can be no other than what ariſes from the *medium* we have proved to be ſpread upon the ſurfaces of bodies.

From all theſe obſervations and experiments we learn, that to make the ſafeſt and beſt Conductor, there is a neceſſity to have it made of one entire piece of metal. But as ſuch a conſtruction may not be obtainable in all caſes, eſpecially when it happens to be of a conſiderable length, the ſeveral joinings of the pieces, which may be found wanting to complete the ſame, ought to be brought ſo cloſe to each other, by ſcrews or otherwiſe, as art can make them; that the *reſiſtance* to the paſſage of lightning may be *diminiſhed* as much as poſſible.

Extracts from letters publiſhed by Dr. FRANKLIN, *in his Treatiſe on Electricity,* p. 395, 396, *and* p. 416 *to* 419; *and which are referred to in* p. 11 *of the preceding letter to* Sir CHARLES FREDERICK.

Letter I. AT Mr. Weſt's houſe, in Philadelphia, " the Conductor, extended in height " about nine feet and a half above a ſtack of chim- " neys, to which it was fixed, (though Mr. Kinnerſley, " the author of this letter, and of ſome curious expe- " riments in Electricity, which are well known, ſup- " poſes three or four feet would have been ſufficient.) " It was ſomewhat more than half an inch in dia- " meter in the thickeſt part, and tapering to the " upper end. The Conductor, from the lower end " of it to the earth, conſiſted of ſquare iron nail- " rods, not much above a quarter of an inch thick; " connected together by interlinking joints. It ex- " tended down the cedar roof to the eaves; and " from thence down the wall of the houſe, four

" ſtory and a half to the pavement in Water-ſtreet, " being faſtened to the wall in ſeveral places by " ſmall iron hooks. The lower end was fixed to " a ring, in the top of an iron ſtake that was drove " about four or five feet into the ground.

" The above-mentioned iron rod had a hole in " the top of it about two inches deep, wherein " was inſerted a braſs wire, about two lines thick, " and, when firſt put there, about *ten inches long*, " terminating in a very acute point, but now, " *(after a ſtroke of lightning)* its whole length was " *no more than ſeven inches and a half*, and *the top* " *very blunt*: that ſome of the metal appeared to be " miſſing, the ſlendereſt part of the wire being, as " he ſuſpected, conſumed into ſmoke. But ſome " of it, where the wire was a little thicker, be" ing *only melted by the lightning*, *ſunk down*, while " in a *fluid ſtate*, and formed a *rough irregular cap*, " lower on one ſide than on the other, round the " upper end of what remained, and *became inti" mately united therewith.*"

II. " TO the outſide of Mr. Raven's chim" ney was fixed a large iron rod, ſeveral feet " in length, reaching above the chimney; and at " the top of this rod the *points were fixed*. From " the lower end of this rod, a ſmall braſs wire was " continued down to the top of another iron rod " driven into the earth. On the ground floor, in " the chimney, ſtood a gun, leaning againſt the " back wall, nearly oppoſite to where the braſs wire " came down on the outſide. The lightning fell " upon the points; did no damage to the rod they

" were fixed to; but the braſs wire, all down till it " came oppoſite to the top of the gun-barrel, was de- " ſtroyed. There the lightning *made a hole through the* " *wall, or back of the chimney, to get to the gun-barrel,* " down which it ſeems to have paſſed; and although " it did not hurt the barrel, it damaged the butt of " the ſtock, and *blew up ſome bricks of the hearth.* " The *braſs wire below the hole in the wall remained* " *good.*"

III. Mr. MAINE, of Indian Land, South Carolina, in a letter, dated Aug. 28, 1760, acquaints us, " that he had a *ſet of electrical points,* " conſiſting of *three prongs,* of *large braſs wire,* tipt " with ſilver, and *perfectly ſharp,* each about ſeven " inches long: theſe were rivetted into an *iron nut,* " about *three quarters of an inch ſquare,* and opened " at top equally to the diſtance of *ſix or ſeven inches,* " *from point to point, in a regular triangle.* This " nut was ſcrewed very tight to the top of an *iron* " *rod,* of above *half an inch diameter,* or the thick- " neſs of a common curtain rod, compoſed of ſeveral " joints, annexed by hooks turned at the end of " each joint, and the whole fixed to the chimney " of his houſe by iron ſtaples. The points were " elevated ſix or ſeven inches above the top of the " chimney; and the lower joint ſunk three feet in " the earth, in a perpendicular direction. The light- " ning broke with a violent exploſion onthe chimney, " *cut the rod ſquare off,* juſt *under* the nut, and, he was " perſuaded, *melted the points, nut, and top of the* " *rod, entirely up;* as after the moſt diligent ſearch, " nothing of either was found, *and the top of the*

“ *remaining rod was caſed over with a congealed* “ *ſolder.* The lightning ran down the rod, *ſtarting al-* “ *moſt all the ſtaples,* and unhooking the joints, with- “ out affecting the rod, *except on the inſide of each hook,* “ *where the joints were coupled, the ſurface of which was* “ *melted, and left as caſed over with congealed ſolder.* No “ part of the chimney was damaged, *only at the foun-* “ *dation,* where it was *ſhattered almoſt quite round,* “ and *ſeveral bricks were torn out. Conſiderable cavi-* “ *ties were made in the earth quite round the founda-* “ *tion,* but *moſt within eight or nine inches of the rod.* “ It alſo ſhattered the bottom weather-board, at one “ corner of the houſe, and made *a large hole in the* “ *earth,* by the corner poſt. On the other ſide of “ the chimney, it *ploughed up ſeveral furrows* in *the* “ *earth ſome yards in length.* It *tore up the hearth* in “ ſeveral places. *A copper tea-kettle,* ſtanding in the “ chimney, was beat together, as if ſome great “ weight had fallen upon it; and *three holes, each* “ *about half an inch in diameter, melted through the* “ *bottom.*” What ſeemed the moſt ſurpriſing to Mr. Maine was, that “ the hearth, under the tea-kettle, “ was not hurt: yet the bottom of the kettle was “ drove inward, as if the lightning proceeded from “ under it upwards, and the cover was thrown to “ the middle of the floor, &c. &c. ——— The “ kitchen, at *ninety feet diſtance,* was full of negroes, “ *who were all ſenſible of the ſhock;* and ſome of them “ told him, that they felt the rod about a minute “ after, when it was *ſo hot* that they could not bear “ it in hand.”

It may not be improper here to obſerve, that conſidering the very many difficulties there are in coming at any facts, particularly philoſophical ones, when they happen in remote countries, as in America, and even in England; it is rather extraordinary to find *three caſes* publiſhed by Dr. Franklin himſelf, where the *pointed parts* of his Conductors, &c. and the buildings they were applied to, were injured by lightning. I make no doubt but that there are many other inſtances, in obſcure places, which have paſſed unnoticed. For all men are not philoſophers: and thoſe who may delight in obſerving curious appearances have not always inclination or opportunity to make them public. There is indeed one inſtance more from *America*, where the pointed part of a Conductor was alſo melted: the account of which was lately communicated to the Royal Society.

William Lyttelton, Eſq; who was Governor of South Carolina ſome years ago, remembers a ſtorm of lightning that fell upon a ſtable which belonged to him, whilſt he reſided there: though his houſe, which was provided with one of thoſe pointed Conductors, was diſtant from the ſtable but about twenty yards; nevertheleſs two of the rafters of the ſtable were ſplit and thrown down by it. To theſe accounts I ſhall ſoon have another to add reſpecting a houſe which was *greatly damaged* by a ſtroke of lightning; notwithſtanding it was alſo provided with a *pointed Conductor*.

I ſhall now put a few queſtions, that may be of uſe in ſome future obſervations, which I propoſe to make at ſome convenient time, upon the *three letters* quoted from Dr. Franklin, as well as upon his remarks at the end of Mr. Maine's letter.

QUESTIONS.

1. Does the houſe of Mr. Maine ſtand upon high or low ground?
2. What is the nature of that ground?
3. Is it generally dry or moiſt?
4. Are there any rivers, ponds, or other waters near it?
5. Are there many other buildings near Mr. Maine's houſe? and what may be the neareſt diſtance of any one of them?
6. What are their heights compared with Mr. Maine's?
7. Whether any of thoſe buildings were provided with Conductors at the time the lightning happened?
8. Were thoſe Conductors circumſtanced as Mr. Maine's Conductor was, in point of elevation, &c. and with *three prongs equally ſharp?*
9. Were any obſervations made upon thoſe neighbouring Conductors, when that of Mr. Maine's was attacked?
10. Are the perſons, who have pointed Conductors to their houſes, provided with a *ſtock of ſharp points,* for the purpoſe of *replacing thoſe that may be deſtroyed by lightning?*
11. Whether a *Mr. Peroneau,* of Charles-Town, in South Carolina, had not his houſe *greatly damaged* by a ſtroke of lightning, notwithſtanding it was provided with a *pointed Conductor?* when did that event happen? and what were the circumſtances that attended it?

12. And whether there are not ſeveral other inſtances in America, which are well known to many, where the lightning has been found to damage the pointed Conductors, or the buildings they were affixed to, or both, at the ſame time?

I SHALL ſum up the whole of this ſubject with a few *general obſervations* on the method of ſecuring buildings from the effects of lightning.

1. Buildings made of *Fir* entirely, having no metal for the faſtnings, ornaments, or conveniencies, are the leaſt liable to be attacked by lightning.
2. Buildings that have more or leſs metal in their conſtruction, &c. or in which the metal is more or leſs connected together, are more or leſs liable to be attacked. The metal, together with the diſpoſition of it in the buildings, being the inducement for the lightning to enter; and the obſtruction made to its paſſage by the other neighbouring materials being generally the cauſe of its dangerous effects, in tearing and daſhing them to pieces.
3. It has therefore been found neceſſary, to connect thoſe metals, by others, from the top of the building to the bottom, and to moiſt ground below it.
4. But as it may be difficult, in many caſes, to make ſuch a connection properly, bars of iron, or leaden ſpouts, extending from the top of the building to the moiſt ground, may be fixed with more eaſe, and perhaps with leſs expence. However, ſuch Conductors will have an advantage over the

the other method, by anſwering the purpoſe of conveying away the lightning more ſafely, *whenever it chances to attack them.*

5. *Sharp points* fixed upon ſuch Conductors are dangerous: for as the lightning is found to act with more power upon them than upon *blunted ends*, in the proportion of at leaſt twelve to one, it ſeems to me, that they are put there only to *invite an enemy* which otherwiſe might not have troubled us; and of which we can by no art diſcover the whole power: and ſhould any extraordinary accumulation of this active matter, be at any time effected in a Conductor, by means of ſo very eaſy a paſſage as is furniſhed by a *point*, there is no ſaying what the conſequences may be. And that clouds ſometimes are able to furniſh ſuch extraordinary accumulations of lightning, and for a conſiderable time together, even after many violent exploſions, there are innumerable inſtances. Among others I remember to have ſeen in Yorkſhire, ſome years ago, between nine and ten in the evening, a very large black cloud, which occaſioned prodigious quantities of lightning, and almoſt inceſſantly, for a conſiderable time together; half an hour at leaſt. But what is more remarkable, the courſe of this black cloud was traced from the South-Weſt of England to the North, or North-Eaſt, of Scotland, and even into Sweden; *cauſing very great lightnings* as it paſt over part, if not the whole land, in that direction. When it paſſed over London, which was about twelve

at noon, the ſame day on which it was ſeen in Yorkſhire, a darkneſs accompanied it, like that of an eclipſe, for a conſiderable time. And that this cloud was the ſame which Profeſſor Bergman obſerved in Sweden, was collected from the different times it was obſerved, at different places, correſponding with its velocity.

N. B. Since the printing of the facts in the preceding papers, reſpecting the Conductors belonging to St. Paul's cathedral, the committee have met and examined them, in all the parts which they could conveniently come at; when certain defects in the conſtruction of them appearing, the committee thought it highly neceſſary they ſhould be rectified directly, together with every other defect, which, upon a more particular examination, might be diſcovered: and thoſe their thoughts were accordingly reported to the Dean and Chapter.

Extracts from authentic papers, *giving an account of of two Magazines of Gunpowder that were ſuppoſed to be blowu up by Lightning: one of them being in* Breſcia, *a large City in the Territories of* Venice; *the other at* Fort Auguſta *in* Jamaica.

Papers relating to the Magazine at Breſcia.

HAVING read ſome *extraordinary accounts* in our daily and monthly publications, of a powder magazine that had been blown up by lightning, at *Breſcia*, in Auguſt 1769, I applied to the Venetian

Ambaſſador to procure me the honour of an anſwer to ſome *queſtions* which I drew up from the hints collected in the public papers: with a view to come at the knowledge of ſuch facts as I apprehended were material, and might be depended upon. I was the more induced to take this ſtep, as I was, about the time of writing the *queſtions,* engaged in drawing up a *report,* which required every information I could obtain, reſpecting accidents by lightning.

The Queſtions propoſed were as follow:

1. Whether the magazine of powder was lodged in a baſtion? and if ſo, what was the height of that baſtion compared with the ground round about it?
2. What kind of materials covered the magazine?
3. And whether ſuch covering was bomb proof?
4. Whether any buildings were in the neighbourhood of the baſtion? and at what diſtance?
5. Whether there was any iron or other metal; and what quaantity of it, over, or upon, the baſtion?
6. What was the quantity of powder lodged in the magazine at the time of the exploſion? and whether *all* the powder was exploded at the time it happened?
7. Whether the blowing up was occaſioned by a a flaſh of lightning?
8. To what diſtance were the largeſt ſtones, or other materials thrown?

9. What number of houſes in general were dedroyed by it? and what number of churches or other large edifices?
10. What was the greateſt diſtance at which houſes were damaged?
11. What were the kind of faſtenings, ſaid to be of the ſtrongeſt nature, that were forced at eighteen miles diſtance? and if not to that diſtance, to what other diſtance were thoſe effects obſerved to take place?
12. Whether any ſtone bridges were thrown down by the exploſion?
13. What was the greateſt diſtance at which the effects were perceived?
14. Whether any cannon were removed from their places, and to what diſtance? and if any were, how were they circumſtanced in point of ſituation, &c.

From VENICE, by the Favour of ——.

Reponſe aux queſtions relatives a l'exploſion de la tour, &c.

A la première. Il n'eſt pas queſtion de magazin à poudre. C'étoit une ancienne tour de 20 toiſes de hauteur ſur 6 de largeur; batie et revetue de pierres de taille fort groſſes: dans laquelle par une grande mégarde on avoit mis 400 livres de poudre. Cette tour étoit placée à la porte meridionale de la ville au dedans des remparts; voici pour la ſeconde et troiſième queſtion auſſi.

A la quatrième. Il y avoit des batimens à très peu de diſtance tant au dedans qu'au dehors de la ville. Les plus proches à quarante pas ſeulement.

A la cinquième. Dans la tour il y avoit quelque barre de fer, quelque grille dans la muraille. Point d'autre metal.

A la ſixième. La quantité eſt marquée ci deſſus.

A la ſeptième. L'exploſion fut occaſionée par un éclair.

A la huitième. A deux milles d'Italie les plus petites: les plus groſſes à un mille, une pierre de 700 livres de poid tombant à un quart de mille de diſtance ſur le comble d'une maiſon l'écraſa avec la mort de 7 perſonnes.

A la neuvième. Plus de 100 maiſons détruites avec une petite égliſe; 200 autres maiſons fort endommagées, avec pluſieurs egliſes. Preſque toutes les autres maiſons, egliſes, et batimens de la ville ont reſſenti le terrible effet de l'exploſion de la tour, du moins pour la quantité prodigieuſe des glaces, et des vitres caſſées.

A la dixième. A la diſtance d'un demi mille d' Italie.

A la onſième. Quelque barre de fer et de bois fut jettée à la diſtance d'un quart de mille d'Italie.

A la douzième. Rien de celà.

A la treiſième. Juſqu'à trente milles d'Italie. Il y eut auſſi quelque petit tremblement juſqu'à cette diſtance dans les murailles des maiſons, occaſioné par l'exploſion. On a amuſé beaucoup la credulité du public, avec des pretendus effets obſervés d'auſſi loin; mais on n'a pas imposé aux eclairés.

A la quatorſième. Deux petits canons ſeulement, placés à la porte de la ville proche de la tour à poudre, furent jettés dans le foſſé à la diſtance de 60 pas.

A l'occaſion de la funeſte exploſion de la tour on remarqua des phenomenes très ſinguliers, et j'oſe dire incroyables à tous ceux, qui ne les ont pas obſervés de leurs propres yeux; quoiqu' ils ſoient très certains. Par exemple il y eut des portes ouvertes d'une façon tout-à-fait extraordinaire; comme la grande porte de l'egliſe nommée la *Pace* placée à un tiers de mille de la tour, laquelle etoit fermée au dedans vers la partie ſuperieure par une groſſe barre de fer, au milieu par un gros verrouil qui avoit ſa ſerrure, et vers l'extremité par un plus petit verrouil avec la ſerrure de même. Or quand l'exploſion arriva, le terrible effort de l'air briſa le bois vers le milieu de la partie ſuperieure de la porte, et detacha la barre: à l'inſtant le petit verrouil à l'extremité inferieure ſe plia au dedans, et ſortit de deux annaux ſans ſortir cependant de ſa ſerrure. Cela n'a rien d'extraordinaire; mais le gros verrouil du milieu ſortit pareillement de ſes deux annaux ne ſortant pas de la ſerrure, et ne ſe trouva nullement plié, ni endommagé en aucune façon. On obſerva ſoigneuſement l'architrave, et le ſeuil de marche, de même que les murailles de la porte, et on ne vit ni elargiſſement, ni derangement de porte. Le même accident arriva à des autres portes plus

petites, et on ne peut abſolument l'expliquer d'une façon raiſonable. C'eſt aux ſcavants Meſſieurs, qui ont proposé les queſtions, à tacher d'eclaircir un fait, qui n'eſt pas moins vrai, qu'incroyable.

The ſame Queſtions anſwered by another hand.

1. The magazine which blew up was erected on the rampart, cloſe to the gate of *Santo Nazaro*, and was elevated about 40 feet from the level of the town.
2. The magazine was built of maſonry, and of a ſquare figure, whoſe exterior ſide did not exceed 30 feet; nor the thickneſs of the walls 6 feet; ſo that the area within did comprehend 324 ſuperficial feet.
3. By obſervations made on many other ſquare towers, ſimilar to that blown up at the gate of *Santo Nazaro*; it may be ſuppoſed that although there was an arch made of maſonry, which covered it, yet it was not ſo thick as to be able to reſiſt the force of a 13 inch ſhell.
4. The diſtance from the gate of *Santo Nazaro*, to the neareſt part of the town, was about 120 feet.
5. Iron bolts, and various ſtraps of iron, ſtrengthened the door of the magazine; therefore it naturally attracted to it the flaſhes of lightning.

6. From the conſtruction of the ſquare tower, (which was only a temporary depoſit for gunpowder) I am ſure it could not contain more than 1000 barrels (viz. 112 pounds in each barrel) if it had been full; but from what I could underſtand when at Breſcia, there was not above half the quantity. The whole quantity of powder was certainly exploded.

7. No other cauſe has ever been aſſigned by the inhabitants of Breſcia, for the blowing up of the magazine, than by lightning; as the exploſion immediately ſucceeded a violent tempeſt of thunder and lightning.

8. Various have been the accounts to what diſtance the largeſt ſtones, and other materials, were thrown: ſome ſay to the diſtance of two miles; but I have ſeen ſtones to the ſize of three hundred weight laying at the diſtance of one thouſand yards from the gate of *Santo Nazaro*, which have been declared to be part of the magazine blowed up.

9. At the extremity of a radius of 1000 feet, forming and comprehending the third part of a circle; houſes were totally deſtroyed, with all the inhabitants buried in the ruins. With preciſion I cannot tell the number of houſes that were deſtroyed; but I ſuppoſe there were between two and three hundred. One church was totally demoliſhed, and another was ſo effected by the exploſion that it was intended to take it down. The Cardinal's Palace, at the diſtance of 1000 feet, built with maſonry, was entirely ruined.

10. By the exploſion many large ſtones of the magazine were thrown into different parts of the town, and broke through roofs and floors of houſes and convents, and did conſiderable damage.
11. I never heard that faſtenings of any kind, even within the town, had been forced by the exploſion, much leſs at the diſtance of 18 miles.
12. No ſtone bridges were affected.
13. The exploſion was felt at Bergamo, a town ſituated upon high ground; diſtant from Breſcia about 30 Italian miles.
14. No cannon were moved from their places.

N. B. Without the gate of *Santo Nazaro*, a circular ravelin is built, which was much leſs affected by the exploſion than one would imagine; yet it clearly ſhews, by the ſituation of the door, that the line of leaſt reſiſtance was towards the body of the place, although the whole miſchief was done within the walls of the town; and I do verily believe, that the iron on the door of the magazine greatly contributed to attract the lightning to that part.

Papers relating to the Magazine at Fort Auguſta, *in* Jamaica.

SIR,

AGreeably to your requeſt I have inſpected my papers, and found, that on the 28th of September, 1763, I wrote a letter to Mr. Wellbore Ellis, then Secretary at War, dated at Spaniſh Town in Jamaica, by which I informed him that, "on "the 14th of that month an unhappy accident happened at Fort Auguſta in that iſland; where a "magazine, containing 2850 barrels of gunpowder, "was blown up by lightning; and the exploſion, "beſides doing much damage to the Fort, killed four "officers, viz. Captain Talbot, Captain Lieutenant "Dunbar, and Enſign Keating, of the 43d regi-"ment; and Lieutenant Monſel of the 74th; and "eleven private men, and wounded ſeventy-ſix more "belonging to thoſe two corps." I have no other paper or document relating to this matter, but I remember that the exploſion happened about nine or ten minutes, as computed, after ſome powder belonging to one of his majeſty's ſhips had been placed in the magazine; and it was ſuppoſed that a train had been formed by ſome of that powder which might have fallen on the ground, from a flaw or crevice in one of the barrels which contained it. I am, with great regard,

SIR,

Your moſt humble ſervant,

W. H. LYTELTON.

Mount-Street,
Feb. 2, 1772.

Extract of a letter from ———, *at* ———, *Kingſton in Jamaica, Sept.* 20, 1763.

I AM extremely ſorry to acquaint your ——— with a moſt ſurprizing accident which happened here the 15th inſtant. The powder magazine at Muſquito Point was then blown up (ſuppoſed by lightning)

lightning) wherein was contained all your ———'s powder under my charge; a particular account thereof I have herewith annexed; likewiſe all the powder of his majeſty's ſhip Valiant was at that time lodged in the ſaid magazine, and has ſhared the ſame fate.

Extract of a letter from ——— *to* ———, *dated on board the* ——— *at Jamaica, Sept.* 21, 1763.

I HAVE nothing particular to mention in addition to what I wrote by the Centaur, but the unlucky accident of the magazine at Fort Auguſta, in Muſquito Point, blowing up the 14th inſtant, with three thouſand barrels of powder in it; by which three officers and about thirty private men were killed, and three officers and upwards of forty men wounded, and the fortification near the magazine much ſhaken. This accident, by moſt people that were in the Fort, is laid to the account of the lightning, but I cannot pretend to inform their ——— to what it was owing. The Valiant's whole ſea-ſtore of powder, near four hundred barrels, had the fate of the reſt in the Fort.

ANOTHER account ſays, that when the magazine at Jamaica blew up, the centinel obſerved a large ball of fire in the air, directing its courſe towards the magazine; upon which he jumped from the rampart into ſome low ground, and was not hurt. That it was ſuppoſed the ball fell upon the center of the arch.. That ſome barracks near the magazine were thrown down, and part of the fortification deſtroyed.—That many of the copper hoops were found twiſted together, and thrown to a great diſtance. That the windows were broke at ſeventeen miles diſtance. That the magazine being ſituated near the ſea, great part of the hoops were ſuppoſed to have fallen therein.

ERRATA.

Page	*Line*	*for*	*read*
11	5	happened.	happened;
17	16	*poſſitively*	*poſitively*
18	5	effects	accidents
22	17	receive	occaſion
48	24	convertability	convertibility
	29	reſiiſter	reſiſter
52	18	Tnis	This

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